Effect of sowing pattern and density on the quality of one-year-old Austrian pine bareroot seedlings

Jovana Devetaković✉, Lučian Krinulović, Ivona Kerkez Janković

Faculty of Forestry – University of Belgrade, Belgrade, Serbia

✉ jovana.devetakovic@sfb.bg.ac.rs

Abstract

Austrian pine (*Pinus nigra* Arnold) seedlings are frequently used for afforestation/reforestation and restoration practice in Serbia. Indeed, the seedlings of various stock types are produced by almost all forest nurseries in Serbia and bareroot seedlings are mostly common. The aim of this study is to analyze the method of sowing and sowing density on some morphological characteristics and quality of one-year-old Austrian pine seedlings. Sowing in rows and random sowing across all seedbed space were performed. In both cases, the sowing density (R1 - 8 g m^{-1}, R2 - 40 g m^{-2}) and half of the recommended sowing density (S1 - 4 g m^{-1}, S2 - 20 g m^{-2}) were applied. Seedlings from both treatments had average height and root collar diameter values in the range of 4.91 to 5.73 cm, and 1.25 to 2.34 mm, respectively. Observed characteristics of seedlings (height - H, root collar diameter - RCD, root length - RL, dry weight of shoot - SDW, root - RDW and seedlings - SLDW, sturdiness coefficient - SQ and quality index - QI) were conditioned by treatment (One-Way ANOVA, p<0.05). Shoot to root ration was similar at seedlings of all treatments and ranged from 1.33 to 1.63. In both cases, decreased density produced better results. The combination of lower sowing density (20 g m^{-2}) and sowing in all seedbed areas (S2) provided the best seedlings with QI - 0.21.

Keywords

Contents

1 Introduction

In Serbia, afforestation/reforestation and restoration activities consider Austrian pine (*Pinus nigra* Arnold) in several cases as suitable species. Last year, 448,000 Austrian pine seedlings were planted exclusively on public property in forest and non-forest land (SORS 2020). According to the same resource, it is between a third and a quarter of all coniferous seedlings planted in 2019 in Serbia. Almost all forest nurseries in Serbia produce Austrian pine seedlings of different stocktypes (Ivetić et al.

2017). However, most nurseries do not have the required equipment for the development of containerized seedlings, so Austrian pine is typically grown from bareroot seedlings. Nursery cultural practices have a great role in a production of quality bareroot seedlings. Sowing density is specifically conditioned on the quantity and quality of the seedlings. Low density in seedbed caused growth of large seedlings with disbalance shoot-root ratio, while high densities make seedlings stunted and spindly and more susceptible to disease (Landis 2008). Two sowing patterns are represented in Serbian nurseries, sowing in rows and random sowing across all seedbed space (Stilinović 1987).

The aim of this study is to evaluate the sowing density and sowing pattern on some morphological attributes and quality of one-year old Austrian pine bareroot seedlings.

2 Materials and methods

Seed source is Austrian pine forest on location Šargan (West Serbia, 43°49'01'' N, 19°28'55'' E, 955 m a.s.l.). Seeds were stored in plastic zip bag at low temperature (2 - 5 °C) for two years. Seed quality (germination percent, moisture content and weight of thousand seeds) after storage was tested in the Laboratory for seed and seedling at the Faculty of forestry, University of Belgrade in March 2016. Germination percentage was tested on the sample of total 400 seeds (4x100) according formula (1) by Ivetić (2013), moisture content was determined by moisture analyzer Kern MLB50-3 and weight of thousand seeds were calculate using formula (2) by Ivetić (2013).

(1) GP (%) = $\frac{\sum Kp}{n} * 100$

Where: GP is germination percentage, *Kp* is germination percentage in each replication, *n* is number of replications.

(2) WTS = $\sum 8x * 1.25$

Where: WTS is weight of thousand seeds and *x* is weight of hundred seeds.

Trail was established in the nursery of the Faculty of Forestry – University of Belgrade in April 2016. Sowing was carried out with forest humus soil in the modified seedbed (Duneman's seedbed). Sowing was performed by hand in rows and random sowing across all space. On first and third trial plots, seeds were sowing in rows: R1 - 8 g m^{-1} (recommended by Stilinović 1987) and R2 - 4 g m^{-1}. The distances between rows were 20 cm and total mass of seed was 40 g m^{-2} and 20 g m^{-2}, respectively. Seed was planted uniformly through all plot space on second and fourth trial plots in the same quantification as first and third plot: S1 - 40 g m^{-2} and S2 - 20 g m^{-2}. Eight plots were established because there were two replications of every single plot (Figure 1).

Germination started at the beginning of May 2016, three weeks after sowing. During germination time, irrigation was conducted every day and later reduced to three times a week. Weed control was performed manually, as needed. Fertilization was missed. There were no symptoms of disease or pathogens during the growing season. Height (H) and root collar diameter (RCD) were measured on a sample of 50 seedlings per plot at the end of the growing season, in October 2016. A sample of 10 seedlings per treatment was taken out and used for further research. Extracted

seedlings were dried at 68 °C ± 2 °C for 48 hours (Ivetić 2013) and dry weight of shoot and root were determined, also as seedling dry weight (SLDW). Shoot and root weights were estimated on an electronic scale with an accuracy of 0.01 g. Shoot to root ratio (S:R) was calculated as ration between shoot dry weight (SDW) and root dry weight (RDW). Root length (RL) was measured after root pressing and scanning using a method described by Ivetić (2013). The sturdiness coefficient (3) was calculated according to Roller (1977), and the quality index (4) was calculated using Dickson et al. (1960) method:

$$(3) \quad SQ = \frac{H \ (cm)}{RCD \ (mm)}$$

$$(4) \quad QI = \frac{SLDW(g)}{\left(\frac{H \ (cm)}{RCD \ (mm)}\right) + \left(\frac{SDW \ (g)}{RDW \ (g)}\right)}$$

Where: H – height (cm), RCD – root collar diameter (mm), SLDW – seedling dry weight (g), SDW – shoot dry weight (g), RDW – root dry weight (g).
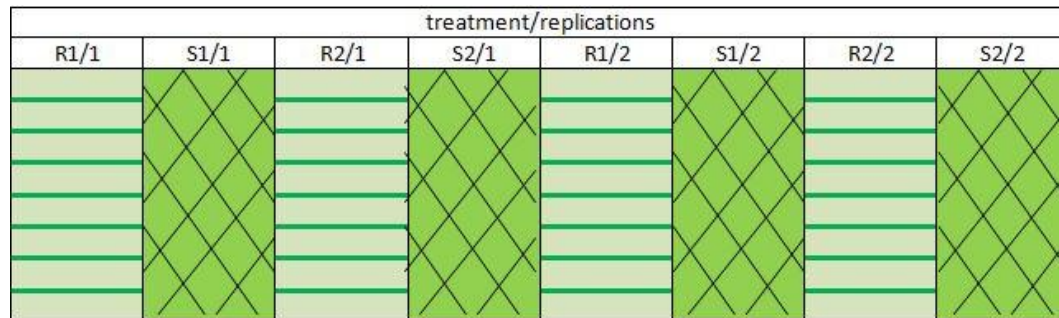

Figure 1. Arrangement of plots inside seedbed according to treatments and their replications.

One-way ANOVA was used to test differences between mean values of measured characteristics between the treatments. Mean values were separated using LSD post-hoc test, with significance level of $p<0.05$. All analyses were performed using STATGRAPHICS Centurion XVI.I.

3 Results and discussion

Seed tests showed 94% of germination in laboratory, 8.018% moisture content and 24.19 g of 1000-seed weight. The two-year seed storage did not result in a decrease in the germination percentage of Austrian pine seeds. According to Grosling (2007), *Pinus* seeds can be stored for 5-15 years with a moisture content of 6-7% at 3-5 °C with limited germination reduction. Bonner (2008) and Stilinović (1985) have recommended similar requirements for orthodox seed short-term storage.

Germination was very high in the seedbed, as in the laboratory, but there was a spontaneous reduction in the production of plants in the seedbed during the growing season. At the end of the growing season, the number of seedlings was higher at R1 and S1 (750-800 m^{-2} at S1, 107-115 seedlings m^{-1} at R1) than at R2 and S2 (450-500 m^{-2} at S2, 65-72 seedlings m^{-1} at R2). Germination in seedbed did not determinate immediately after germination, but number of seedlings at the end of growing season

showed that germination percentage was near 50%. This result confirmed averment (Stilinović 1987) that germination in seedbed is 50-70% from laboratory germination.

Sowing pattern gave clear differences between seedlings. Seedlings from S1 and S2 treatments were better compared to R1 and R2 treatments, respectively (Table 1). Sowing in rows provides limited space to produce seedlings and more pronounced seedling competition (R1 and R2) than random sowing in all plot space. Most nurseries have chosen sowing in rows because mechanization in cultural practice is best used (Landis 2008, Stilinović 1987). For manual sawing or very precise mechanical drills, random sowing across all spaces needs skilled staff (Stilinović 1987). Mechanical drills have a better plant schedule than manual sowing of seedbeds (Landis 2008), so smaller fluctuations in seedlings schedule on all plots in this trail can be explained as a result of manual sowing.

Table 1. The average values (standard deviation), minimal and maximal values of Austrian pine seedlings characteristics per treatment and their differences.

	Values	Treatments				ANOVA	
		R1	R2	S1	S2	F	p
RCD (mm)	mean (SD)	1.25[a] (0.42)	1.60[b] (0.50)	1.42[c] (0.30)	2.34[d] (0.62)	113.2626	0.0000
	min-max	0.50-2.40	0.50-2.90	0.70-2.30	1.10-3.60		
H (cm)	mean (SD)	5.73[c] (1.71)	4.91[a] (1.00)	5.39[b] (1.02)	5.70[bc] (1.01)	10.5929	0.0000
	min-max	2.00-9.80	2.70-7.70	2.60-8.90	3.50-8.50		
RL (cm)	mean (SD)	32.85[a] (12.65)	64.21[b] (32.49)	62.70[b] (20.75)	67.20[b] (19.22)	5.1027	0.0048
	min-max	11.80-50.30	29.10-121.00	37.70-100.60	41.60-106.00		
SDW (g)	mean (SD)	0.12[a] (0.05)	0.25[b] (0.14)	0.31[b] (0.08)	0.51[c] (0.18)	17.1196	0.0000
	min-max	0.06-0.21	0.07-0.56	0.23-0.48	0.21-0.80		
RDW (g)	mean (SD)	0.08[a] (0.03)	0.20[b] (0.12)	0.22[b] (0.07)	0.40[c] (0.16)	14.8429	0.0000
	min-max	0.04-0.13	0.07-0.42	0.14-0.32	0.17-0.64		
SLDW (g)	mean (SD)	0.20[a] (0.09)	0.45[b] (0.25)	0.53[b] (0.13)	0.91[c] (0.34)	17.0291	0.0000
	min-max	0.10-0.33	0.14-0.98	0.39-0.80	0.38-1.44		
S:R	mean (SD)	1.63 (0.31)	1.38 (0.58)	1.5 (0.42)	1.33 (0.20)	1.1363	0.3474
	min-max	1.22-2-20	0.92-2.86	0.93-2.36	1.05-1.62		
SQ	mean (SD)	5.02[d] (2.14)	3.29[b] (0.97)	3.99[c] (1.26)	2.55[a] (0.61)	65.1061	0.0000
	min-max	1.67-11.28	1.32-6.80	1.52-8.9	1.56-4.17		
QI	mean (SD)	0.02[a] (0.01)	0.10[b] (0.07)	0.11[b] (0.04)	0.21[c] (0.1)	14.6106	0.0000
	min-max	0.01-0.05	0.03-0.24	0.06-0.21	0.08-0.37		

[*]Tukey post-hoc test, $p<0.05$

Sowing density also influenced distinctions between seedlings, so in the case of dense sowing seedlings were weaker in comparison to less frequent sowing (R1 and S1, respectively R2 and S2). The characteristics of one-year-old Austrian pine seedlings are highly reliant on treatment, which is the pattern and sowing density interaction (Table 1).

Seedlings from all treatments had H lower than 6 cm and RCD lower than 2 mm, except S2 (2.34 mm). Seedlings from this trail can be marked as 2nd class according Serbian standards for forest seedlings (JUS D.Z2.110) and did not suitable for planting at the field. Seedlings from this trial had lower quality than average one-year old Austrian pine bareroot seedlings from Serbian nurseries (Ivetić at al. 2017). Ivetić and Škorić (2013) reported slightly higher one-year old Austrian pine bareroot seedlings at seedbed density 500 seedlings m[-1], but with RCD in the same range and lower QI and RL.

At S2 treatment, root collar diameter, root length, dry weights (SDW, RDW and SLDW) and quality index were highest where space was the largest per single seedling. On the other hand, at treatment R1, H was the highest in seedlings, where RL was markedly the lowest. Root length is good indicator of the vitality of Austrian pine seedlings (Chiatante 2002), thus, R1 seedlings can be classified as the weakest. In R1 treatment, seedlings were in very competitive conditions, causing intensive growth in height with a low diameter and high SQ relative to other treatments. Seedlings from the treatment R1 had a SQ value of 5.02, which is within the range of acceptable values (Roller 1977), while seedlings from other treatments were sturdy with relatively stronger RCD than H. Riley and Steinfeld (2005) have previously reported low influences of seedbed density on the height of the coniferous seedlings, also as a strong influence on RCD and root growth. Jinks and Mason (1998) reported a strong influence of the seedlings density on RCD and dry weights of shoot and root which is in accordance with our results. Mataruga et al. (2012) reported higher RCD values and more than double values of SDW and RDW in comparison to our study for one year old Austrian pine seedlings in seedbed density 300 seedlings.m^{-2}, but S:R ration was in the same range as in this study. The S:R ratio is lower than desirable 2:1 at all treatments and it can be marked as acceptable (Barnier et al. 1995). The QI indicate seedlings from S2 as "fair" and as "poor" from other treatments (Dickson et al. 1960).

4 Conclusions

The sowing pattern and sowing density have a strong impact on the consistency of the seedlings. In all seedbed spaces, random sowing gives better results than row sowing, but this approach involves mainly manual work and minimal use of mechanization and cultural practice. In both cases, lower density gives better results. The best seedlings are supported by a combination of lower sowing density (20 g m^{-2}) and sowing across the entire seedbed space.

5 Acknowledgements

6 References

Bonner FT (2008) Storage of Seeds. In: Bonner FT, Karrfalt RP (Eds) The Woody Plant Seed Manual. Agriculture Hand Book 727, USDA Forest Service, Chapter 4, p. 85-95.

Chiatante D, Di Iorio A, Scippa GS, Sarnataro M (2002) Improving vigour assessment of pine (*Pinus nigra* Arnold.). Plant Byosyst 136: 209-216. https://doi.org/10.1080/11263500212331351109

Dickson A, Leaf AL, Hosner JF (1960) Quality appraisal of white spruce and white pine seedling stock in nurseries. The Forest Chronicle 36: 10-13. https://doi.org/10.5558/tfc36010-1

Gosling P (2007) Raising Trees and Shrubs from Seed. Forestry Commission Practice Guide, Forestry Commission, Edinburgh, p. 1-28.

Ivetić (2013) Praktikum iz semansrtva, rasadničarstva I pošumljavanja. Šumarski fakultet - Univerzitet u Beogradu, 1-213. [In Serbian]

Ivetić V, Škorić M (2013) The impact of seeds provenance and nursery production method on Austrian pine (*Pinus nigra* Arnold) seedlings quality. Ann For Res 56(2): 297-305.

Ivetić V, Maksimović Z, Kerkez I, Devetaković J (2017) Seedling quality in Serbia - Results from three-year survey. Reforesta 4: 27-53. https://doi.org/10.21750/REFOR.4.04.43

Jinks R, Mason B (1998) Effects of seedlings density on the growth of Corsican pine (*Pinus nigra var. maritime* Melv.), Scots pine (*Pinus sylvestis* L.) and Douglas-fir (Pseudotsuga menziesii Franco) in containers. Annales des Sciences Forestieres 55: 407-423. https://doi.org/10.1051/forest:19980402

Landis (2008): Nursery practices. In: Bonner FT, Karrfalt RP (ed): The woody plant seed manual. Agriculture Hand Book 727, USDA Forest Service, Chapter 7, p.125-145.

Mataruga M, Haase D, Isajev V, Orlovic S(2012) Growth, survival and genetic variability of Austrian pine (*Pinus nigra* Arnold) seedlings in response to water deficit. New Forest 43: 791-804. https://doi.org/10.1007/s11056-012-9351-7

Riley LE, Steinfeld D (2005) Effects of bareroot nursery practices on tree seedling root development: an evolution of cultural practices at J. Herbert Stone nursery. New Forest 30(2-3): 107-126. https://doi.org/10.1007/s11056-005-1379-5

Roller KJ (1977) Suggested minimum standards for containerised seedlings in Nova Scotia. Department of Fisheries and Environment Canada, Canadian Forestry Service, Information Report M-X-69, 18 p.

SORS (2020) Statistical Buillten - Foresty in Republic of Serbian 2019. Statistical office of the Republic of Serbia, 660: 1-70. [In Serbian]

Stilinović S (1985) Semenarstvo šumskog i ukrasnog drveća i žbunja. Šumarski fakultet - Univerzitet u Beogradu, 1-399. [In Serbian]

Stilinović S (1987) Proizvodnja sadnog materijala šumskog i ukrasnog drveća i žbunja. Šumarski fakultet - Univerzitet u Beogradu, 1-454. [In Serbian]